Silage

ESCA

HARVESTING SYSTEMS FOR WILTED SILAGE

[East of Scotland College Agriculture.
Economics and management dept]

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HARVESTING SYSTEMS for WILTED SILAGE

J. D. Elrick

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CONTENTS

SUMMARY

1. This report is based on a 2-year study of wilted silage systems, involving 35 sets of field observations over 2 seasons (1972 and 1973). Twenty-five whole season records were also returned by farmers.

2. **Harvester performance**

Swath weight affects rate of work but the particular combination of yield, degree of wilting and width of mower which produces a given weight of swath is of no importance.

In light swaths, about 4 mph (say 16 tons per hour) can be expected with any size of tractor from 60 to 100 hp. In heavy swaths, 55/60 hp tractors will be limited to about 2 mph (say 18 tons per hour), compared with perhaps 3 mph (24 tons per hour) for 65 to 100 hp tractors. The advantage of 90+ hp is only likely to become apparent in very heavy swaths when output should be at least 30 tons per hour.

Considerably higher rates than the above are possible, but are not likely to be achieved consistently except by determined operators.

3. **Wide mowers** can result in a greatly improved pick-up rate but only in the case of larger tractors (say 70+ hp). Smaller tractors are less able to take advantage of the heavier swath (see 2 above).

Two-into-one swath turners may give similar benefits if the machine used can produce a stone-free double swath of even consistency.

4. **Wilting** to 30 per cent dry matter (DM) makes the swath at least 40 per cent lighter, which can allow higher pick-up rates. However, a gain in trailer capacity is not to be expected, so the overall result may be no different (if transport arrangements are already the limiting factor). Buckrake performance (tons DM per hour) should be at least 50 per cent better with good wilting.

5. **Precision-chop (P.C.) harvesters** were no faster than double-chop (D.C.) machines, other things being equal (such as tractor size, swath weight and adequate transport). But the effect on trailer capacity can be important – trailers can hold approximately 40 per cent more P.C. material than D.C. material. Although P.C. machines are generally considered to be more easily damaged, less time was lost from breakdowns of P.C. machines in this survey than from D.C. machines.

6. **Side loading** (i.e. trailers **not** hitched to the harvester) can speed up the operation by at least 20 per cent in conditions where trailers have to be changed frequently; e.g. trailers of only standard size, a fast pick-up rate, or D.C. material (which takes up more space).

7. **Systems**

Details of 6 systems are included, covering a range of performance from 1.0 to 2.7 acres per hour (expected overall rate). A simple guide to selection is also given.

INTRODUCTION

Since wilting and chopping are generally regarded as good practice at the present time, a 2-year study of silage making systems was carried out on farms where:

(i) **wilting** was practised;

(ii) the swath was picked up by either a **double-chop** or a **precision-chop** forage harvester;

(iii) the silage was made in a **horizontal** clamp.

The objective was to clarify the effect on performance of alternative items of equipment and the way in which they are organised.

It is hoped that this report of the results will reduce the lengthy process of trial and error by which silage-making systems are commonly adopted and adapted on the individual farm.

The information comes from two sources.

(i) Stop-watch studies in the field, based on 35 visits made in 1972 and 1973. Recording methods did not interfere with the progress of work; and, because of the efforts which were made to carry out these studies unobtrusively, it is considered that our presence had little effect on rate of work.

(ii) Records kept by farmers for the whole period of the 1st cut. Twenty-five satisfactory records were returned.

Part 1 presents the main findings as briefly as possible. Part 2 gives details of alternative systems, based on these findings. The Appendices give methods and results in detail.

The following definitions should be noted.

Spot rate is the rate of work during non-stop operation (e.g. when the harvester is actually picking up the swath).

Overall rate includes turns, trailer changes and any other delays which are part of the normal routine. This rate can be maintained throughout the working day (ignoring mealtimes, breakdowns and changing fields).

Swath 'weight' means weight per unit of distance (usually lb/10 yd).

Swath 'width' refers to the effective width of cut taken by the mower.

PART 1: RESULTS AND DISCUSSION

This section contains the main conclusions supported by only a summary of the data. A fuller presentation of the results can be found in the Appendices.

1. The effect of power on harvester performance

(a) 55/60 hp v. 65/75 hp.

Both the precision-chop (P.C.) and double-chop (D.C.) type of harvester can be used with a tractor of only 55 hp. However, the lower rate of work may with smaller tractors not be acceptable in heavy swaths, whether these are the result of heavy yields, poor wilting or wide mowers (Table 1).

TABLE 1: The effect of power and swath weight on harvester performance (spot rate of work)

	EXPECTED RATE OF WORK					
	Swath weight:					
	light	medium	heavy	light	medium	heavy
Tractor size:	mph			tons per hour		
55/60 hp	3.8	2.8	2.1	16	18	18
65/75 hp	3.8	3.1	2.8•	16	20	24

Notes: 1. 'Light' = 55 lb/10 yd. 'Medium' = 82.5 lb/10 yd. 'Heavy' = 110 lb/10 yd.

The 'medium' swath corresponds to the average of 32 fields sampled.

2. These are not maximum rates but those to expect in practice from average drivers. Some drivers, prepared to operate nearer the maximum can improve on these rates by at least 20 per cent.

3. Detailed results in Appendix B.

In heavy crops, the smaller tractor has little in reserve and drivers can be expected to ease off to keep noise and stress to reasonable levels; larger tractors are better able to maintain forward speed.

In light crops, considerations of comfort and general control of the equipment will tend to limit forward speed to no more than about 4 mph with both sizes.

Fifty-five hp tractors are likely to be unsatisfactory in combination with P.C. harvesters when these are set for a very fine chop (e.g. for tower silos).

(b) 65/75 hp v. 90+ hp

On average, tractors in the 90+ hp class were no faster than 65/75 hp models (Appendix B). However, there is little doubt that they have extra potential. For example, one 90 hp tractor was recorded at 36 tons per hour (4.2 mph in a heavy swath). But the potential is not likely to be realised unless:

(i) a heavy swath is made;

(ii) the driver maintains at least 3.5 mph (except in the heaviest crops);

(iii) transport arrangements can cope with the output;

(iv) a precision-chop harvester is used. (Double-chop harvesters are usually designed for use with tractors of no more than 75 hp).

2. The advantages of wide mowers

Wide rotary mowers (9ft nominal width) took an effective cut of 7.8 ft on average, compared with 4.5 ft for mowers of 5 ft nominal width. The increase in swath weight (approximately 75 per cent) will normally slow down the harvester, but only by about 25 per cent if a 65/75 hp tractor is used (see mph v. swath weight trend in Appendix B). The result is a gain of 40 per cent in tons per hour. Smaller tractors are unlikely to benefit from a heavier swath (Table 1).

Faster mowing is another feature which makes wide mowers a desirable component of really high performance harvesting systems.

3. Two-into-one swath turners v. wide mowers

Ground-driven turners should be avoided because they tend to rake stones into the swath and, in common with up-and-over types, the double swath they produce appears to feed much less evenly into the harvester.

Machines which do not have these faults are likely to give the same benefits as a wide mower. They may even be preferable for haylage systems where it is sometimes desirable to disturb the swath in any case for faster wilting. However, they do introduce an extra operation into the system, and any advantage will be lost if:

(i) the pick-up operation is sometimes delayed as a result.

(ii) a tractor of only 55/60 hp is used with the harvester. Although the tractor may not be brought to a standstill by the double swath, an improvement in tons per hour is not to be expected except in the lightest crops.

4. Double-chop v. precision-chop

The precision-chop harvester was originally developed for the benefit of tower silo systems where the short-chop material packs down better and can be removed more easily. Their use with clamp systems is claimed to improve the fermentation process and to reduce losses through better consolidation which excludes air more successfully. Double-chop material is longer and presumably less effective in providing these benefits. However, this study was only concerned with field performance aspects.

(a) Rate of work

Rate of work in tons per hour was similar with both types of harvester (Table 2).

TABLE 2: Spot rate of work — double-chop v. precision-chop

Type of harvester	Mph	Tons/hour	Hp	Swath weight
D.C. (12 observations)	3.0	19.9	65	84 lb/10 yd.
P.C. (23 observations)	3.2	19.4	75	82 lb/10 yd.

The difference in mph is to be expected as a result of the higher average hp in the P.C. sample (see Table 1).

The figure for acres per hour was higher for the P.C. sample (2.2 v. 1.7) but again this fact is unrelated to type of harvester. Instead, it is a direct result of swath width (5.7 ft v. 4.5 ft) and larger tractors, the extra width of swath being due to a number of wide mowers and 2-into-1 swath turners. (In spite of the difference in swath **width,** swath **weight** is similar in both cases because of slightly better wilting and rather lower yields to start with in the P.C. sample.) The conclusion must be that, other things being equal, pick-up rate is unaffected by type of harvester.

(b) Effect on trailer capacity

Chopped grass is known to pack more closely than unchopped grass, but a substantial difference is also evident between double- and precision-chop material (Table 3).

TABLE 3: Trailer capacity — double-chop v. precision-chop material

Type of harvester	Tons of DM per 100 cu ft of trailer capacity
D.C. (9 observations)	0.123
P.C. (21 observations)	0.175

Note: Detailed results in Appendix C.

Precision-chopping increases trailer capacity by approximately 40 per cent and since transport delays are in fact fairly common with D.C. systems, this effect must be regarded as one of the main advantages of the more expensive harvester. It is probably the main reason for the better whole-season rates of work recorded by farmers using P.C. machines (Table 4).

TABLE 4: Whole-season rates of work (acres/hour)

Type of harvester	1972	1973
Double-chop	0.77 (5 farms)	1.16 (8 farms)
Precision-chop	0.88 (5 farms)	1.40 (7 farms)
Difference	+11%	+12%

Even if transport is not a limiting factor, some improvement in rate of work will result from fewer stops to change trailers.

(c) Reliability

It is recognised that stones and other objects can cause serious damage to the precision-chop mechanism. Simple flail harvesters are better adapted to survive damage from such materials. Double-chop harvesters are generally thought to be of intermediate susceptibility.

The results of this study do not allow comparisons to be made on this particular aspect of reliability. However, breakdowns occur for various reasons apart from the intake of foreign bodies (e.g. failure of bearings, shafts, shear pins, axles and hitches) and when breakdowns from all causes are considered (Table 5), there appears to be no reason to discriminate against the P.C. harvester.

TABLE 5: Reliability comparison — double-chop v. precision-chop

	Double-chop	Precision-chop
Time lost due to breakdowns (as % of working hours)	6.7% (range: 0-22)	4.3% (range: 0-14)
No. of working hours recorded	1189	705
No. of records	14	11

Nevertheless the results cannot be taken as proof of **better** reliability — the small difference could easily arise by chance when individual results vary so widely; or it could be the effect of newer machines in the P.C. sample.

5. The advantages of wilting

Wilting is good practice from the husbandry point of view:

(i) the chances of an undesirable type of fermentation are much reduced (especially when ensiling grass with a low sugar content);

(ii) losses of DM in effluent and in the fermentation process are reduced;

(iii) problems of effluent disposal may be avoided;

(iv) higher DM intake is possible with wilted silage and the profitability of many livestock systems is related to this factor.

These effects will be noticeable to some extent even with slight wilting but best overall results depend on reaching a DM content of 25-30 per cent.

Harvesting systems can also benefit from good wilting in a number of ways:

(a) Effect on harvester performance

A swath wilted to 25 per cent DM is about 28 per cent lighter than when cut fresh as, say, 18 per cent DM, or about 42 per cent lighter if wilted to 30 per cent DM.

In practice, 25 per cent DM is the level more commonly reached after a 24-hour wilt and this (referring to Table 1) is enough to reduce a 'heavy' swath to a 'medium' swath, or a 'medium' swath to a 'light' swath. The improvement in forward speed which this reduction allows can be substantial, especially for the smaller tractor.

For a given weight of swath, DM content does not appear to affect rate of work, at least within the usual range (18 to 33 per cent DM).

(b) Effect on trailer capacity

It is sometimes suggested that wilting increases the DM capacity of trailers, but the results of this study do not show this to be the case, either for D.C. or P.C. material (Appendix B). This means that the improvement in harvester potential (see above) will not improve the overall performance of the system unless transport arrangements are already more than adequate.

However, although trailer loads contain no more DM, they do contain much less water (Table 6).

TABLE 6: Expected capacity of standard trailer [1]

DM content	Weight of DM (tons)		Weight of grass (tons)	
	D.C.	P.C.	D.C.	P.C.
18%	0.44	0.63	2.5	3.5
25%	0.44	0.63	1.8	2.5
30%	0.44	0.63	1.5	2.1

(1) 'Standard' trailer = 10 x 6 x 6 ft.

This reduction in weight can sometimes be important. When hitched to the harvester, heavy loads can be dangerous on steep, downhill slopes; speed may be affected when working uphill and the harvester wheels may sink in soft ground, although this depends partly on trailer design.

(c) Effect on buckrake performance

Wilting can greatly increase buckrake performance (Table 7).

TABLE 7: **Effect of wilting on buckrake performance (spot rate)**

DM content	Tons of grass/hour	Tons DM/hour
20%	20	4.0
25%	21	5.4
30%	22	6.8

Note: Detailed results in Appendix B (Figure 3).

Since actual tons of grass per hour is apparently unaffected by DM content, tons of DM per hour is largely proportional to the degree of wilting.

6. Factors affecting buckrake performance

The average spot rate of work was 21.5 tons per hour.

Above-average performance depends on:

(a) good wilting (see above);

(b) good operators. (The fastest 5 operators averaged 32 tons per hour, the slowest 5 only 13.6 tons per hour);

(c) good equipment, and in particular powerful tractors. A clutchless forward/reverse gear change, double rear wheels and a wide buckrake are among the options which make high performance easier to achieve. Industrial or 4-wheel-drive tractors have enough performance to cope with any situation — one second-hand industrial tractor with a front-mounted buckrake was timed at a leisurely 64 tons per hour;

(d) good chopping. (The rate with P.C. material was slightly higher than with D.C. material — 23.0 v. 19.4 tons per hour).

Assistance at the clamp should not be necessary when handling P.C. material, especially if a push-off buckrake is used and the load can be deposited as a layer instead of in a heap. Even with D.C. material, the driver was usually unassisted.

7. Routines

The same basic routine (described overleaf) was used for almost all the systems studied. However, the trailers were sometimes hitched to the harvester ('rear' loading) or towed independently ('side' loading). The latter arrangement reduces idle time but requires an extra man and tractor. Appendix C gives more detail for various combinations of yield, trailer size, etc.

(a) **Harvester routine**

Element	Minutes per load: average	Minutes per load: range	No. of observations	Notes
Pick-up swath	7.6	3.9 – 14.8	35	Time depends on trailer size as well as rate of work
Turn	1.0	0.3 – 1.9	31	One 0.5 min turn per 320 yd row on average
Change over: rear loading	1.8	1.0 – 3.2	20	Automatic hitch
(or side loading)	(0.5)	(0.2 – 0.9)	(8)	A non-stop change–over is possible but a pause was more usual to avoid any loss of grass
Total	10.4 (rear loading) or 9.1 (side loading)			

(b) **Transport routine**

Element	Minutes per load: average	Minutes per load: range	No. of observations	Notes
Field travel	2.4	1.2 – 4.8	18	From harvester to gate (return). Slower speeds than on the road.
Road travel	6.0	1.7 – 17.2	21	From gate to clamp (return). Average mph was 11½ (range 7-19½).
Change over: rear loading	2.1	1.0 – 4.4	16	Automatic hitch
(or side loading)	(0.5)	(0.15 – 0.6)	(8)	See 'harvester routine'.
Tip at clamp	2.5	1.4 – 4.7	28	Tipping on a dump area–no trailers were being driven over the clamp.
Total	13.0 (rear loading) 11.4 (side loading)			

Self-unloading trailers feeding into a blower were timed on one farm on 2 separate occasions. Average turn-round times were 6.6 and 9.2 minutes. Tipping trailers are preferable in most circumstances.

(c) Buckrake routine

The average time to clear a load was 6.4 minutes (21.5 tons per hour). However, with most layouts, the buckrake cannot operate continuously because access to the grass dump is prevented for about 2 minutes of the trailer tip routine. On average, the overall rate to expect would therefore be one load per 8.4 minutes (16.4 tons per hour).

(d) Matching routines

Delays will occur if the transport routine is longer than the harvester routine, unless 3 trailers are used instead of 2, in which case the permissible transport routine time is doubled. An increase in trailer size allows extra time, roughly in proportion to the increase in trailer size. In practice, transport delays were fairly common, although sometimes disguised by a reduction in speed by the harvester.

Delays at the clamp were rare but they can easily occur if some special equipment (see Part 1.6(c) page 11) is not included as part of a high performance system.

PART 2: SYSTEMS

1. The main alternatives

The systems in Table 8 provide a range of performance options, from 1.0 to 2.7 acres per hour, by selection from the following equipment:

Mowers	5 ft or 9 ft (nominal width)
Tractors	60, 75 or 90+ hp (approximately)
Harvesters	D.C. or P.C.
Trailers	4 sizes:

1. Small (260 cu ft, eg 9½ x 5½ x 5 ft)
2. Standard (360 cu ft, eg 10 x 6 x 6 ft)
3. Large (488 cu ft, eg 12 x 6½ x 6¼ ft)
4. Outsize (588 cu ft, eg 14 x 7 x 6 ft)

The effect of these alternatives on rate of work has already been discussed in Part 1. Three possible trailer combinations are given for each system, along with the maximum time **available** for road travel if delays are to be avoided. To estimate the actual time **required** for road travel it is necessary to time the trailer over the return journey at realistic speeds. Average figures (say 5 minutes per mile) are a poor substitute because road conditions vary so much from farm to farm.

TABLE 8: **Six wilted silage systems — a guide to rate of work and transport requirements**[1]

	Yield of DM[2]: Loading arrangement:	2 tons/acre rear	2 tons/acre side	3 tons/acre rear	3 tons/acre side
SYSTEM 1	Acres per hour (overall)	1.4	1.7	1.0	1.2
	Time available for road travel with:	mins		mins	
D.C. harvester,	2 x size 2 trailers	2.2		1.2	
60 hp tractor and	2 x size 3 trailers	4.9		3.6	
5 ft mower	3 x size 1 trailers	7.4		6.2	
SYSTEM 2	Acres per hour (overall)	1.4	1.7	1.1	1.4
	Time available for road travel with:	mins		mins	
D.C. harvester,	2 x size 2 trailers	2.2		0.7	
75 hp tractor and	2 x size 3 trailers	4.9		3.0	
5 ft mower	3 x size 1 trailers	7.4		5.4	
SYSTEM 3	Acres per hour (overall)	1.5	1.7	1.0	1.3
	Time available for road travel with:	mins		mins	
P.C. harvester,	2 x size 2 trailers	5.3		4.0	
60 hp tractor and	2 x size 3 trailers	9.2		7.4	
5 ft mower	3 x size 1 trailers	12.0		10.2	
SYSTEM 4	Acres per hour (overall)	1.5	1.7	1.2	1.4
	Time available for road travel with:	mins		mins	
P.C. harvester,	2 x size 2 trailers	5.3		3.2	
75 hp tractor and	2 x size 3 trailers	9.2		6.3	
5 ft mower	3 x size 1 trailers	12.0		9.0	
SYSTEM 5	Acres per hour (overall)	2.1	2.4	1.8	2.0
	Time available for road travel with:	mins		mins	
P.C. harvester,	2 x size 2 trailers	2.3		0.6	
75 hp tractor and	2 x size 3 trailers	5.1		2.8	
9 ft mower[3]	3 x size 2 trailers	11.6		8.2	
SYSTEM 6	Acres per hour (overall)	2.4	2.7	2.0	2.3
	Time available for road travel with:	mins		mins	
P.C. harvester,	2 x size 3 trailers	3.8		1.6	
90/100 hp tractor and	3 x size 2 trailers	9.8		6.6	
9 ft mower[3]	3 x size 3 trailers	14.6		10.2	

(1) Further details in Appendix C.

(2) The average of 32 fields sampled was 2.3 tons per acre. Five fields were 3 tons per acre or more, and 10 fields were less than 2 tons per acre (some of these were second cut or had been grazed earlier in the year). In all cases, the crop is assumed to be wilted to 25 per cent DM.

(3) A 2-into-1 swath turner is a possible alternative (but see Part 1: 3, page 6).

Comments on Table 8

(a) Transport

Two size 1 trailers cannot keep up with any of these systems, and they can be filled so quickly that even a small transport delay will result in the harvester spending more time out of the crop than in it (especially if rear loading).

Apart from more or bigger trailers, time available for transport can be increased by a change to P.C. (ie system 3 or 4 instead of system 1 or 2). Also, if the best driver is put on transport, he may beat the average times for change over, field travel and tipping.

Side loading gives more loads per hour, but the time available for road travel hardly changes. (This is because approximately 1½ minutes are saved from both the harvester and transport routines.)

(b) Fast operators

For a given system and crop yield some harvester operators can be expected to drive up to 20 per cent faster than average. Haulage capacity needs to be generous to take proper advantage, unless the transport driver is also faster than average. (Conversely some operators will be up to 20 per cent slower than average and they should be encouraged to do better.)

(c) Buckrake

Performance with systems 5 and 6 needs to be above average. Some of the special equipment options already mentioned will avoid a bottleneck and save the driver's energy for overtime.

(d) Team size

Complete systems need 4-6 men:

	Rear loading:		Side loading:	
	2 trailers	3 trailers	2 trailers	3 trailers
	number of men			
Mower	1	1	1	1
Harvester	1	1	1	1
Buckrake	1	1	1	1
Trailers	1	2	2	3
Total	4	5	5	6

Workable systems are possible with fewer men:

3 men

The harvester is idle in the morning while one man mows. He is then part of the pick-up/transport/buckrake team in the afternoon and evening. This system suits farms where other work has to be done in the morning.

Direct harvesting eliminates the mowing operation and provides an alternative 3-man system, possibly for 9 hours per day instead of 6 with the wilting system (in which case a larger area can be harvested each day).

2 men

One man picks-up and drives to the clamp without unhitching from the harvester. The other man buckrakes. Mowing is again a morning operation by one of the 2 men. A good performance is possible if fields are adjacent to the clamp and suitable equipment is available (ie an outsize trailer with automatic tail gate).

Direct harvesting makes a longer day possible, but the outsize trailer, accommodating up to 5 tons of fresh double-chop material, would be a mistake in some conditions (see Part 1.5(b) page 10).

Two-man systems are generally less satisfactory than making the team up to 3 or 4 through co-operative or contract labour.

(e) Making the systems work

Careful selection of the major items of equipment does not guarantee success — systems can founder on minor details. For example, of the 25 whole-season records kept by farmers, the slowest overall rate (0.59 acres per hour) was returned for a farm with some of the best equipment (heavy-duty precision-chop harvester, 95 hp tractor, and new 12 ft x 6½ ft trailers). A poor hitching system on the transport tractor (5.9 minutes change-over) was keeping the harvester waiting for trailers.

Further weaknesses to avoid are:

(i) obstructions inside trailers which prevent the load tipping out easily;

(ii) tailgates which can only be opened and closed with sledge-hammers;

(iii) inadequate hydraulic oil output for fast tipping;

(iv) tractors without enough braking power for safe, fast road travel;

(v) poor servicing and adjustment of harvesters.

(f) Cost

Appendix E gives current equipment prices. The **initial** cost of setting up a particular system depends on how much existing equipment is either suitable as it stands or acceptable as a trade-in.

The **difference in annual cost** of using various alternatives is easier to estimate (see below). The difference applies irrespective of whether both are new items under consideration or whether one of the alternatives already exists on the farm.

Equipment options		Approximate difference in:			
		Initial cost	Depreciation[1]	Interest[2]	Total[3]
		£	£ per annum		
75 hp	v. 90 hp tractor	1000	125	90	215
D.C.	v. P.C. harvester	800	135	70	205
5 ft	v. 9 ft mower	1000	125	90	215
2 x size 2	v. 2 x size 3 trailers	800	100	70	170

(1) Traded in for ½ price after 3 years for harvesters and 4 years for other equipment.

(2) At 12 per cent on average value.

(3) Depreciation + interest only.. Differences in fuel and repairs likely to be negligible.

2. System selection

The best compromise between cutting early for higher digestibility and later for higher yield, depends on individual livestock systems. But, having come to a decision on this point, it is always desirable to complete the operation in as short a time as possible in order to achieve:

(a) a consistent silage quality;

(b) quick filling and sealing of the clamp to minimise conservation losses.

High performance is not the only way to meet these objectives — choice of variety, early season grazing on some fields etc, can minimise the range of maturity in the clamp; two small clamps can be individually filled and sealed faster than a single large clamp; and long hours can substitute for a high rate of work. Variation in working hours can in fact be considerable (Table 9).

TABLE 9: Hours worked per day [1]

	Farm A	Farm B	Average of 6 farms
1972	3.6	8.0	5.8
1973	3.6	8.1	6.3

(1) Calculated as total working hours for the harvest ÷ number of days elapsed between start and finish. Both A and B harvested between 60 and 70 acres.

Of the 6 farms keeping records over 2 years, the longest and shortest hours were worked by the same farms in both years. The difference was due to working 7 days per week until 8.30 p.m. in the case of farm B; and 5 days per week until only 5 p.m. on Farm A.

A suggested procedure is outlined below to take some account of these variables when selecting a system.

		EXAMPLE:
1.	Decide the acreage of 1st cut silage	80 acres
2.	Choose a suitable duration for the operation (if more than 14 days, remember that the weather may not be suitable around the date you would prefer to start)	10 days
3.	Choose a figure between 3.5 and 8.0 for the number of hours per day you expect to work. Six hours is about average (see Table 9 and text.) These figures take account of weather, breakdowns, Sundays off, etc.	6 hours per day
4.	Calculate working hours per season	60 hours (10 days x 6 hours)

	EXAMPLE:
5. Calculate required rate of work	1.3 acres per hour (80 acres ÷ 60 hours)
6. Refer to Table 8 (page 16) and related comments to see which system will (a) give approximately the required rate of work (b) cope with road travel on the farm (c) suit the number of men available (d) cost as little as possible to adopt	System 4 with 2 x size 3 trailers, rear delivery
7. If the answer at 6 appears too expensive, go back and look for a way out (eg, is a longer harvest tolerable, can you out-perform the average with a cheaper system, can you arrange more overtime?)	

APPENDICES

Appendix A:

Field study methods

The studies usually covered 5 complete **loads** per farm. Two observers with stop-watches were present, one in the field and one at the clamp. Continuous time sheets were kept of the activity at each station, including trailer arrivals and departures.

1. **Physical measurements**

Row length	A measuring wheel was used.
Swath weight	Six 10-yard samples, chosen at random from the area of the field being harvested, were weighed using a canvas sheet and spring balance.
Swath width	Each reading was one tenth of a single measurement spanning 10 rows. The procedure was carried out at least twice.
DM content	A number of samples were taken from each load as it was tipped at the clamp. They went for analysis in a single polythene bag.
Yield	This was calculated from swath weight and swath width.

2. **Work measurement**

The main results were calculated as follows:

Mph (harvester) — from length of row and minutes per row.

Acres per hour (harvester spot rate) — from mph and swath width.

Tons per hour (harvester spot rate) — from mph and swath weight.

Mph (road travel) — from gate-to-clamp times, and distance as recorded on the car odometer or measured on a large-scale map.

Tons per load — from length of swath per load and swath weight. The length of part rows in a load was calculated from the timesheet. For example, if a trailer change occured after 1 minute in a particular row, and each 300 yard row was being picked up in 3 minutes, the split was taken as 100 yards to the first trailer and 200 yards to the second. Since all stops, starts, turns, etc were recorded, this method proved entirely satisfactory.

Tons DM per load – from tons per load and DM per cent.

Tons per hour (buckrake) – from tons per load and minutes to clear each load.

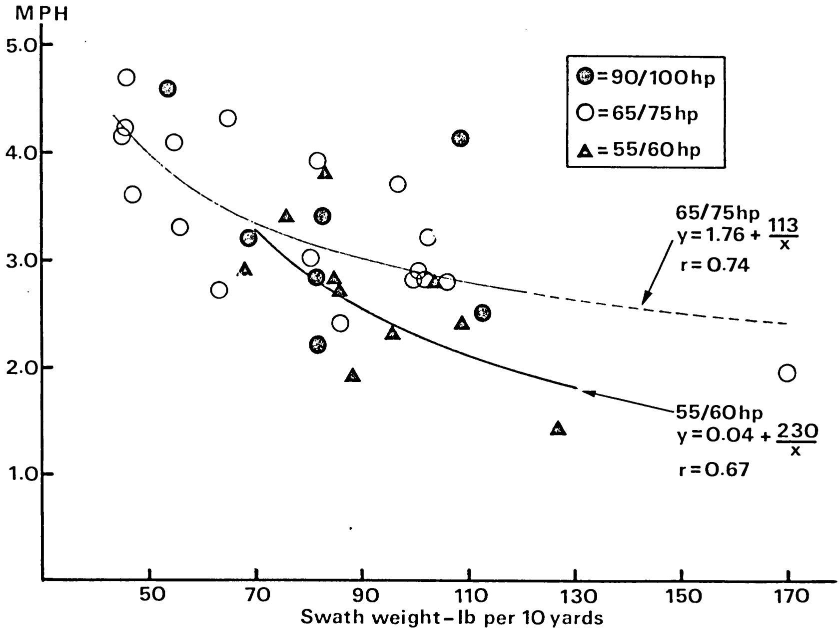
Tons DM per hour (buckrake) – from tons per hour and DM per cent.

Appendix B

The results in detail

The 3 figures which follow present the results for both years together. This provides a wider range of conditions for analysis. For example, no swath weights below 65 lb per 10 yards were recorded in 1972 (because of poorer wilting and higher yields).

FIGURE 1: Harvester forward speed v. swath weight and tractor hp



Notes: The advantage of 65/75 hp does not become apparent until swath weight becomes relatively heavy.

The trend for 90+ hp tractors is not shown as it almost exactly overlaps the 65/75 hp line, indicating a tendency not to take advantage of the extra power. However, as in the 55/60 v. 65/75 comparison, it is likely that the benefit of 90+ hp would become more obvious in heavier swaths (say, upwards of 120 lb/10 yd). Such weights would be common when using wide mowers or working in a double swath.

A great deal of variation remains unexplained by swath weight and tractor hp. Multiple regression analysis showed that type of harvester and swath DM provide little explanation. The most likely reasons for the residual variation are:

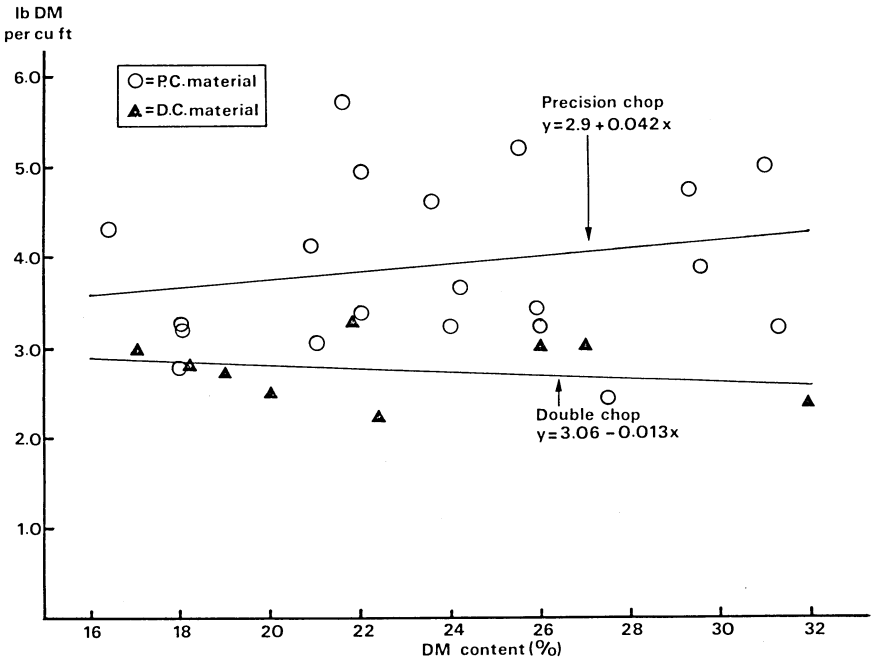
(i) the individual driver;

(ii) differences in gearing between models of tractor;

(iii) some swaths less regular than others. In lumpy swaths, speed might be determined by lumps rather than the average weight.

(iv) adjustment of speed to match transport arrangements (it is pointless to work faster than the ability of the trailers to cope with the output).

FIGURE 2: Trailer capacity v. DM content



Notes: The average figures are:

(i) 3.92 lb DM per cu ft (P.C. material)

(ii) 2.76 lb DM per cu ft (D.C. material)

The difference is highly significant.

Within these 2 categories, the variation is not explained in any way by the degree of wilting (in neither case does the slope of the line approach significance at the 10 per cent level. In other words, there is no reason to consider the lines to be anything other than horizontal).

Probable reasons for the observed variation are:

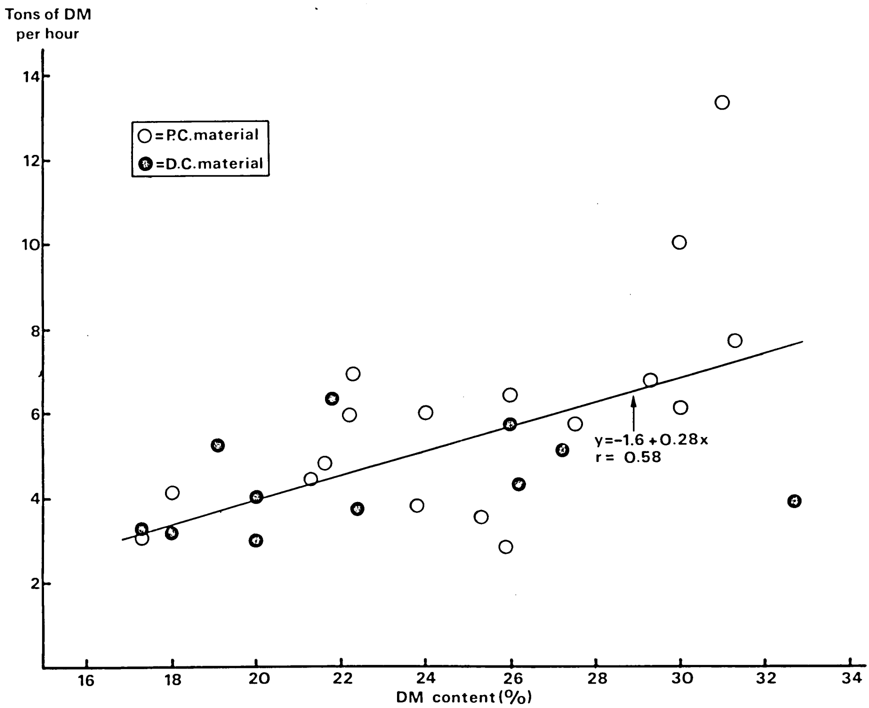
(i) machines set to give a different length of chop; (both machines are adjustable within limits);

(ii) trailers were more completely topped up on some farms than on others (although results were only included if the loads could reasonably be described as full when changed);

(iii) the effective capacity of some trailers is reduced because of a cut-away at the front or side to give better access for the stream of grass from the harvester spout.

The graph points were calculated using nominal internal dimensions.

FIGURE 3: Buckrake performance v. DM content



Notes: Each graph point is the average of approximately 5 loads.

The industrial loader result was not included in the regression analysis.

The correlation between rate and DM per cent is highly significant.

Results are obviously similar for D.C. and P.C. material in the 18-28 per cent DM range. In a direct comparison of average rates, P.C. material appears to have the advantage (5.3 v. 4.3 tons of DM per hour) but this is due to a number of good performances with material in the high DM range where D.C. material is not very well represented.

Some of the poorer rates were clearly due to:

(i) unhurried operators using low gears and low revs;

(ii) poor technique with push-off buckrakes;

(iii) difficult layout (in one case, where the grass dump was outside, the driver had to duck his head each time he passed through the shed door);

(iv) stage of the clamp. Good rates of work are easier in the early stages.

Appendix C:

Systems 1 to 6 in detail

These tables cover a wider range of trailer combinations than Table 8 and show the arithmetic of available road-travel time in detail.

To avoid delay, the transport routine must take no longer than the harvester routine (2 trailers). With 3 trailers, the transport routine can be up to twice as long without causing delay.

Rear loading is assumed throughout, but side loading can be up to 32 per cent faster when trailer changes are frequent, which may be due to small trailers or a fast rate of fill (see bottom line of each table).

In all cases the crop is assumed to be wilted to a DM content of 25 per cent.

SYSTEM 1: Double-chop harvester, 60 hp tractor and 5 ft mower

Trailer size and number according to requirements — rear loading

	Yield of DM:	2 tons/acre				3 tons/acre			
	Trailer size: (see Part 2.1, page 15)	1	2	3	4	1	2	3	4
		Minutes per load				Minutes per load			
HARVESTER ROUTINE	Pick-up swath	4.6	6.3	8.6	10.4	4.2	5.7	7.8	9.4
	Turns	0.8	1.1	1.5	1.8	0.6	0.7	1.0	1.2
	Change over	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
	TOTAL	**7.2**	**9.2**	**11.9**	**14.0**	**6.6**	**8.2**	**10.6**	**12.4**
TRANSPORT ROUTINE	Change over (2.1), field travel (2.4), tip (2.5)	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
	Time left for ROAD TRAVEL	*0.2*	*2.2*	*4.9*	*7.0*	—	*1.2*	*3.6*	*5.4*
2 TRAILERS	**TOTAL**	**7.2**	**9.2**	**11.9**	**14.0**	**—**	**8.2**	**10.6**	**12.4**
	Change over, etc.	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
	Time left for ROAD TRAVEL	*7.4*	*11.4*	*16.8*	*21.0*	*6.2*	*9.4*	*14.2*	*17.8*
3 TRAILERS	**TOTAL**	**14.4**	**18.4**	**23.8**	**28.0**	**13.2**	**16.4**	**21.2**	**24.8**
SPOT RATE OF WORK	Mph	3.8				2.8			
	Acres/hour	2.1				1.5			
	Tons/hour	16.7				18.4			
OVERALL RATE OF WORK	Acres/hour	1.34	1.43	1.51	1.55	0.95	1.04	1.10	1.14
	Tons/hour	10.7	11.4	12.1	12.4	11.7	12.8	13.5	14.0
Difference in overall rate of work with SIDE LOADING		+22%	+17%	+12%	+11%	+23%	+18%	+13%	+12%

SYSTEM 2: Double-chop harvester, 75 hp and 5 ft mower

Trailer size and number according to requirements — rear loading

	Yield of DM:	2 tons/acre				3 tons/acre			
	Trailer size: (see Part 2.1, page 15)	1	2	3	4	1	2	3	4
		Minutes per load				Minutes per load			
HARVESTER ROUTINE	Pick-up swath	4.6	6.3	8.6	10.4	3.8	5.2	7.2	8.6
	Turns	0.8	1.1	1.5	1.8	0.6	0.7	1.0	1.2
	Change over	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
	TOTAL	**7.2**	**9.2**	**11.9**	**14.0**	**6.2**	**7.7**	**10.0**	**11.6**
TRANSPORT ROUTINE	Change over (2.1) field travel (2.4), tip (2.5)	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
	Time left for ROAD TRAVEL	*0.2*	*2.2*	*4.9*	*7.0*	–	*0.7*	*3.0*	*4.6*
2 TRAILERS	**TOTAL**	**7.2**	**9.2**	**11.9**	**14.0**	–	**7.7**	**10.0**	**11.6**
	Change over, etc.	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
	Time left for ROAD TRAVEL	*7.4*	*11.4*	*16.8*	*21.0*	*5.4*	*8.4*	*13.0*	*16.0*
3 TRAILERS	**TOTAL**	**14.4**	**18.4**	**23.8**	**28.0**	**12.4**	**15.4**	**20.0**	**23.2**
SPOT RATE OF WORK	Mph	3.8				3.1			
	Acres/hour	2.1				1.7			
	Tons/hour	16.7				20.4			
OVERALL RATE OF WORK	Acres/hour	1.34	1.43	1.51	1.55	1.04	1.15	1.22	1.26
	Tons/hour	10.7	11.4	12.1	12.4	12.5	13.8	14.7	15.1
Difference in overall rate of work with SIDE LOADING		+22%	+17%	+12%	+11%	+28%	+21%	+15%	+13%

SYSTEM 3: **Precision-chop harvester, 60 hp tractor and 5 ft mower**

Trailer size and number according to requirements — rear loading

	Yield of DM:	2 tons/acre				3 tons/acre			
	Trailer size: (see Part 2.1, Page 15)	1	2	3	4	1	2	3	4
		Minutes per load				Minutes per load			
HARVESTER ROUTINE	Pick-up swath	6.5	8.9	12.2	14.7	6.0	8.2	11.2	13.5
	Turns	1.2	1.6	2.2	2.6	0.8	1.0	1.4	1.7
	Change over	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
	TOTAL	**9.5**	**12.3**	**16.2**	**19.1**	**8.6**	**11.0**	**14.4**	**17.0**
TRANSPORT ROUTINE	Change over (2.1) field travel (2.4), tip (2.5)	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
	Time left for ROAD TRAVEL	*2.5*	*5.3*	*9.2*	*12.1*	*1.6*	*4.0*	*7.4*	*10.0*
2 TRAILERS	**TOTAL**	**9.5**	**12.3**	**16.2**	**19.1**	**8.6**	**11.0**	**14.4**	**17.0**
	Change over, etc.	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
	Time left for ROAD TRAVEL	*12.0*	*17.6*	*25.4*	*31.2*	*10.2*	*15.0*	*21.8*	*27.0*
3 TRAILERS	**TOTAL**	**19.0**	**24.6**	**32.4**	**38.2**	**17.2**	**22.0**	**28.8**	**34.0**
SPOT RATE OF WORK	Mph	3.8				2.8			
	Acres/hour	2.1				1.5			
	Tons/hour	16.7				18.4			
OVERALL RATE OF WORK	Acres/hour	1.43	1.51	1.57	1.61	1.05	1.12	1.17	1.19
	Tons/hour	11.4	12.1	12.6	12.9	12.8	13.7	14.3	14.6
Difference in overall rate of work with SIDE LOADING		+16%	+12%	+9%	+8%	+17%	+13%	+11%	+9%

SYSTEM 4: **Precision-chop harvester, 75 hp tractor and 5 ft mower**

Trailer size and number according to requirements — rear loading

	Yield of DM:	2 tons/acre				3 tons/acre			
	Trailer size: (see Part 2.1, page 15)	1	2	3	4	1	2	3	4
		Minutes per load				Minutes per load			
HARVESTER ROUTINE	Pick-up swath Turns Change over	6.5 1.2 1.8	8.9 1.6 1.8	12.2 2.2 1.8	14.7 2.6 1.8	5.4 0.8 1.8	7.4 1.0 1.8	10.1 1.4 1.8	12.2 1.7 1.8
	TOTAL	**9.5**	**12.3**	**16.2**	**19.1**	**8.0**	**10.2**	**13.3**	**15.7**
TRANSPORT ROUTINE	Change over (2.1), field travel (2.4), tip (2.5)	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
	Time left for ROAD TRAVEL	*2.5*	*5.3*	*9.2*	*12.1*	*1.0*	*3.2*	*6.3*	*8.7*
2 TRAILERS	**TOTAL**	**9.5**	**12.3**	**16.2**	**19.1**	**8.0**	**10.2**	**13.3**	**15.7**
	Change over, etc.	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
	Time left for ROAD TRAVEL	*12.0*	*17.6*	*25.4*	*31.2*	*9.0*	*13.4*	*19.6*	*24.4*
3 TRAILERS	**TOTAL**	**19.0**	**24.6**	**32.4**	**38.2**	**16.0**	**20.4**	**26.6**	**31.4**
SPOT RATE OF WORK	Mph Acres/hour Tons/hour	3.8 2.1 16.7				3.1 1.7 20.4			
OVERALL RATE OF WORK	Acres/hour Tons/hour	1.43 11.4	1.51 12.1	1.57 12.6	1.61 12.9	1.16 13.9	1.24 14.9	1.29 15.5	1.32 15.9
Difference in overall rate of work with SIDE LOADING		+16%	+12%	+9%	+8%	+19%	+14%	+10%	+9%

SYSTEM 5: **Precision-chop harvester, 75 hp tractor and 9 ft mower**

Trailer size and number according to requirements — rear loading

	Yield of DM:	2 tons/acre				3 tons/acre			
	Trailer size: (see Part 2.1, page 15)	1	2	3	4	1	2	3	4
		Minutes per load				Minutes per load			
HARVESTER ROUTINE	Pick-up swath	4.9	6.6	9.1	11.0	3.8	5.2	7.2	8.6
	Turns	0.7	0.9	1.2	1.5	0.4	0.6	0.8	1.0
	Change over	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
	TOTAL	**7.4**	**9.3**	**12.1**	**14.3**	**6.0**	**7.6**	**9.8**	**11.4**
TRANSPORT ROUTINE	Change over (2.1), field travel (2.4), tip (2.5)	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
	Time left for ROAD TRAVEL	*0.4*	*2.3*	*5.1*	*7.3*	–	*0.6*	*2.8*	*4.4*
2 TRAILERS	**TOTAL**	**7.4**	**9.3**	**12.1**	**14.3**	–	**7.6**	**9.8**	**11.4**
	Change over, etc.	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
	Time left for ROAD TRAVEL	*7.8*	*11.6*	*17.2*	*21.6*	*5.0*	*8.2*	*12.6*	*15.8*
3 TRAILERS	**TOTAL**	**14.8**	**18.6**	**24.2**	**28.6**	**12.0**	**15.2**	**19.6**	**22.8**
SPOT RATE OF WORK	Mph	2.95				2.54			
	Acres/hour	2.80				2.41			
	Tons	22.4				28.9			
OVERALL RATE OF WORK	Acres/hour	1.85	1.99	2.11	2.15	1.53	1.65	1.77	1.82
	Tons/hour	14.8	15.9	16.8	17.2	18.3	19.8	21.2	21.8
Difference in overall rate of work with SIDE LOADING		+21%	+17%	+12%	+11%	+29%	+22%	+15%	+13%

SYSTEM 6: Precision-chop harvester, 90/100 hp tractor and 9 ft mower

Trailer size and number according to requirements – rear loading

	Yield of DM:	2 tons/acre				3 tons/acre			
	Trailer size: (see Part 2.1, page 15)	1	2	3	4	1	2	3	4
		Minutes per load				Minutes per load			
HARVESTER ROUTINE	Pick-up swath	4.2	5.7	7.8	9.4	3.2	4.4	6.0	7.3
	Turns	0.7	0.9	1.2	1.5	0.4	0.6	0.8	1.0
	Change over	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
	TOTAL	**6.7**	**8.4**	**10.8**	**12.7**	**5.4**	**6.8**	**8.6**	**10.1**
TRANSPORT ROUTINE	Change over (2.1), field travel (2.4), tip (2.5)	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
	Time left for ROAD TRAVEL	–	*1.4*	*3.8*	*5.7*	–	–	*1.6*	*3.1*
2 TRAILERS	**TOTAL**	**–**	**8.4**	**10.8**	**12.7**	**–**	**--**	**8.6**	**10.1**
	Change over, etc.	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
	Time left for ROAD TRAVEL	*6.4*	*9.8*	*14.6*	*18.4*	*3.8*	*6.6*	*10.2*	*13.2*
3 TRAILERS	**TOTAL**	**13.4**	**16.8**	**21.6**	**25.4**	**10.8**	**13.6**	**17.2**	**20.2**
SPOT RATE OF WORK	Mph	3.5 (1)				3.0 (1)			
	Acres/hour	3.3				2.8			
	Tons/hour	26.4				34.0			
OVERALL RATE OF WORK	Acres/hour	2.07	2.34	2.38	2.44	1.66	1.81	1.95	2.02
	Tons/hour	16.5	17.9	19.1	19.5	20.2	22.0	23.7	24.6
Difference in overall rate of work with SIDE LOADING		+24%	+18%	+14%	+12%	+32%	+23%	+17%	+15%

(1) See text (Part 1.1, (b) page 6)

Appendix D:

The good silage guide [1]

1. Apply fertiliser at correct rate: (80-100 units nitrogen is adequate for the first cut. No fertiliser should be applied within 3 weeks of cutting.

2. Match grass strains to intended cutting dates. Use special grass silage mixture whenever possible. Avoid the inclusion of very early perennial ryegrass.

3. Start cutting during settled weather, as soon as crop bulking permits.

4. Wilt, to obtain a 25-30 per cent DM silage.

5. Additives are desirable in many situations, eg:
   - (a) When only slight wilting has been achieved, especially with second and third cut material where nitrogen content is high and sugar content is low;
   - (b) for legume rich swards;
   - (c) when direct harvesting (recent trial work showed improved livestock performance where additives were used).

6. Pick up the wilted swath with a double-chop or precision-chop forage harvester to achieve a chop length of 1½-6 inches.

7. Fill silo as quickly as possible, using Dorset wedge technique, keeping filling-ramp short. Keep the sides full. A push-off buckrake is a great help. If filling is interrupted cover with polythene sheet.

8. Seal with polythene sheet immediately on completion. Weight sheet down overall with bales, tyres or whatever. Randomly scattered weight is useless. Airtight silo walls are essential to minimise waste.

9. Match your machinery and its organisation to the acreage involved. Consistently good silage is made by those who can clear acres quickly when weather conditions are good.

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(1) Extracted from "Lothian Farming Notes Spring 1974," published by the East of Scotland College of Agriculture Advisory Service.

Appendix E:

Equipment prices (spring 1974)

		Typical basic price	Range	Extras
Tractors [1]		£	£	
45 hp		1500	1450-1700	Weights, oversize tyres, hitches, automatic transmissions, etc.
55 hp		1800	1750-1900	
60 hp		1850	1850-1900	
70-75 hp		2150	2100-2250	
85-95 hp		3000	3000-3500	
Forage harvesters				
Flail:	40" - 43"	550	480-600	Hydraulic pick-up hitch (approx. £100)
	48" - 52"	650	610-800	
	60"	850	830-1000	
Double-chop:	60"	900	880-1000	Hydraulic pick-up hitch (approx. £100)
	72"	1600	—	
Precision-chop:	standard	1700	1600-1700	Hydraulic pick-up hitch (Approx. £100)
	heavy duty	2300	2000-2600	
Mowers				
Cutter bar:	5′	200	180-220	
Flail:	5′	500	400-760	
	6′	700	650-820	
Rotary:	5′	550	450-570	
	7′	800	530-850	
	9′	1500	1500-1700	
Mower/ conditioner:	5′	650	650-1150	
	9′	2000	—	

		Typical basic price	Range	Extras
		£	£	
Trailers (2)				
4 ton	2 wheel	360	310-360	Silage sides from
5 ton	2 wheel	450	420-650	£100 to £150
6 ton	2 wheel	550	520-600	
	4 wheel, tandem	700	650-770	
7 ton	4 wheel, tandem	800	750-860	
8 ton	4 wheel, tandem	900	700-900	
10 ton	4 wheel, tandem	1100	960-1200	

Notes: (1) 2-wheel drive;
with cab, lights and standard tyres;
models offered by major British manufacturers;
recommended prices, late 1973.

(2) Platform size varies from make to make;
typical sizes are 60 sq ft for 4-ton (eg 10′ x 6′)
90 sq ft for 7-ton (eg 13′ x 7′)
120 sq ft for 10-ton (eg 16′ x 7½′).